



EURO
MAINTENANCE

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Maintainability of assets: a pillar of sustainability

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SUSTAINABILITY

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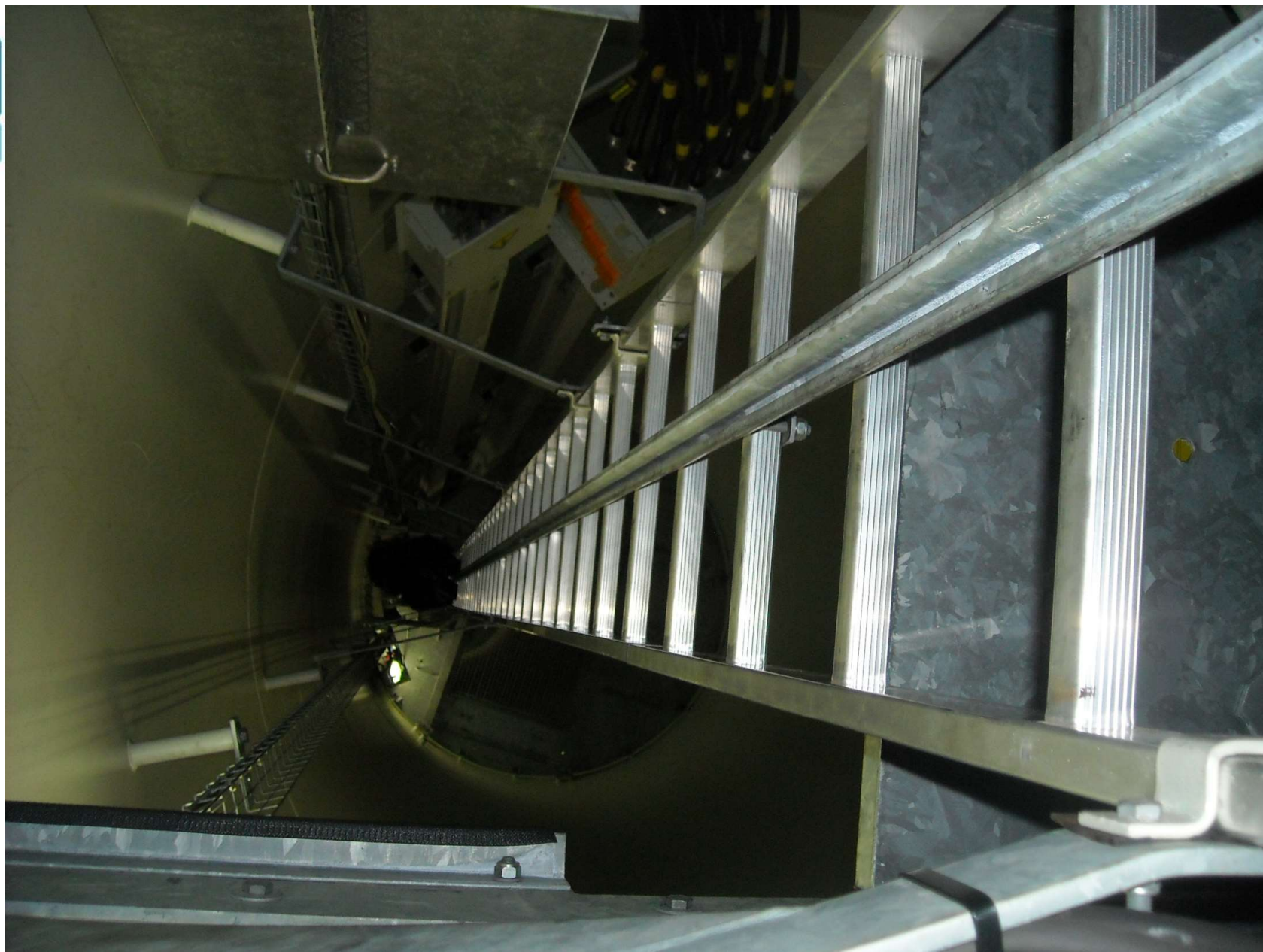
SUMMARY

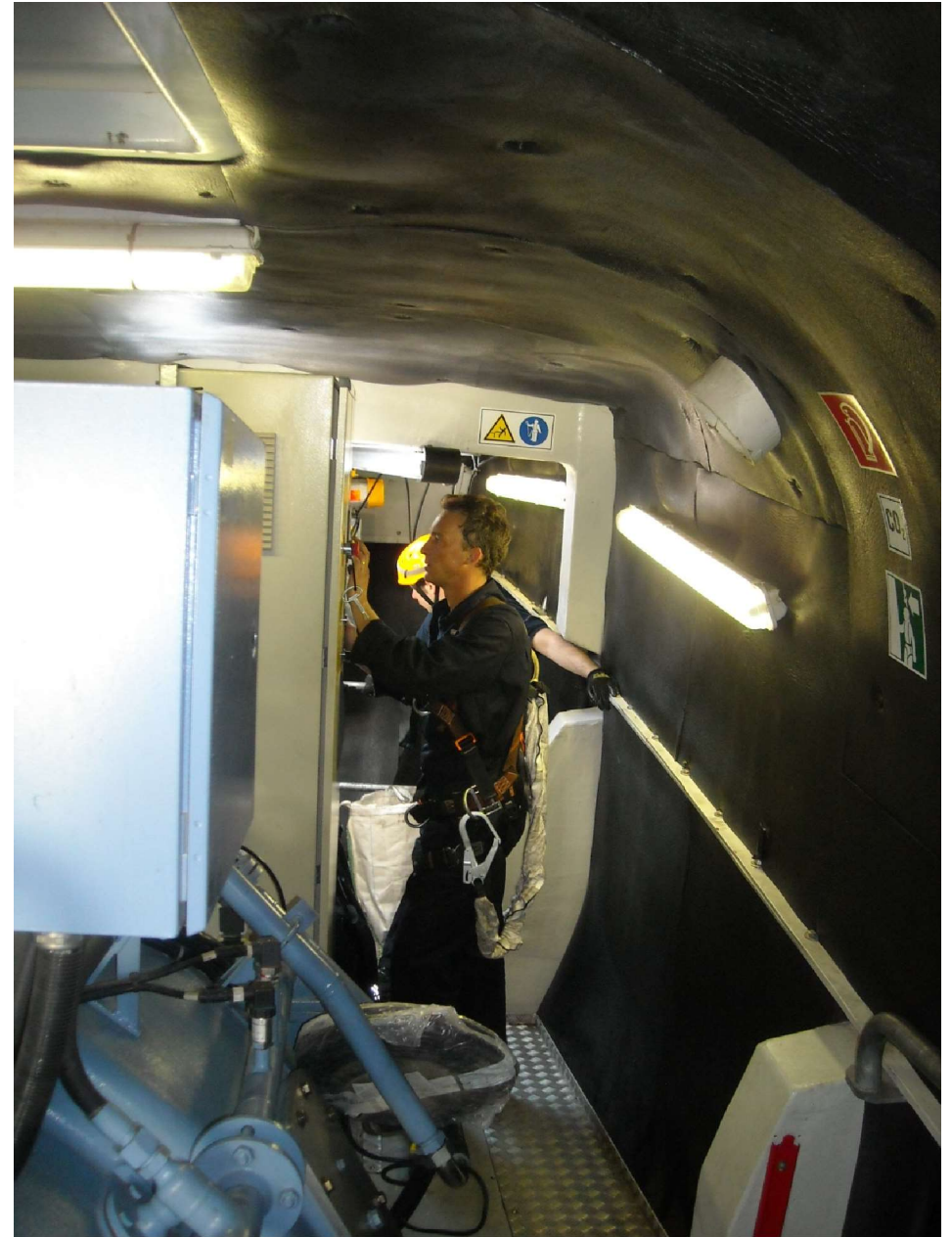
Sustainability

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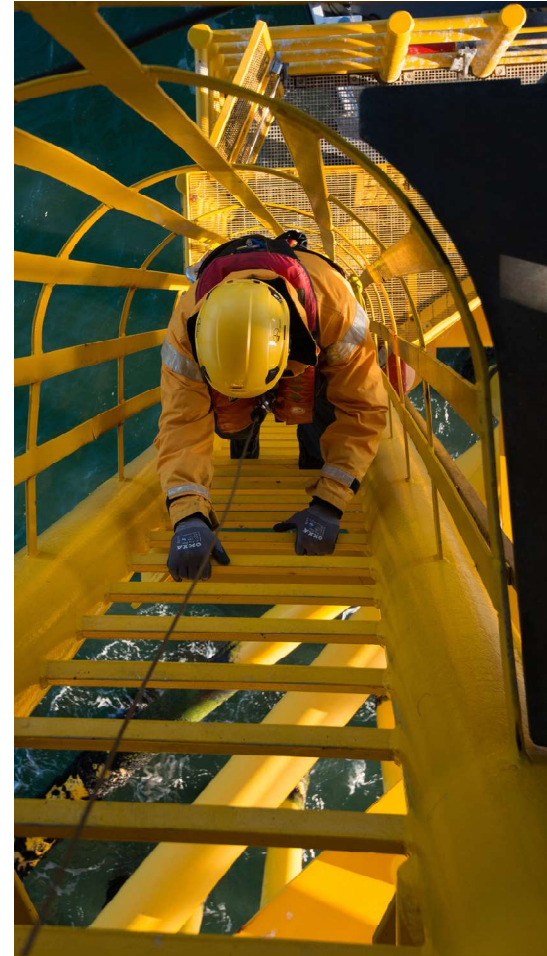
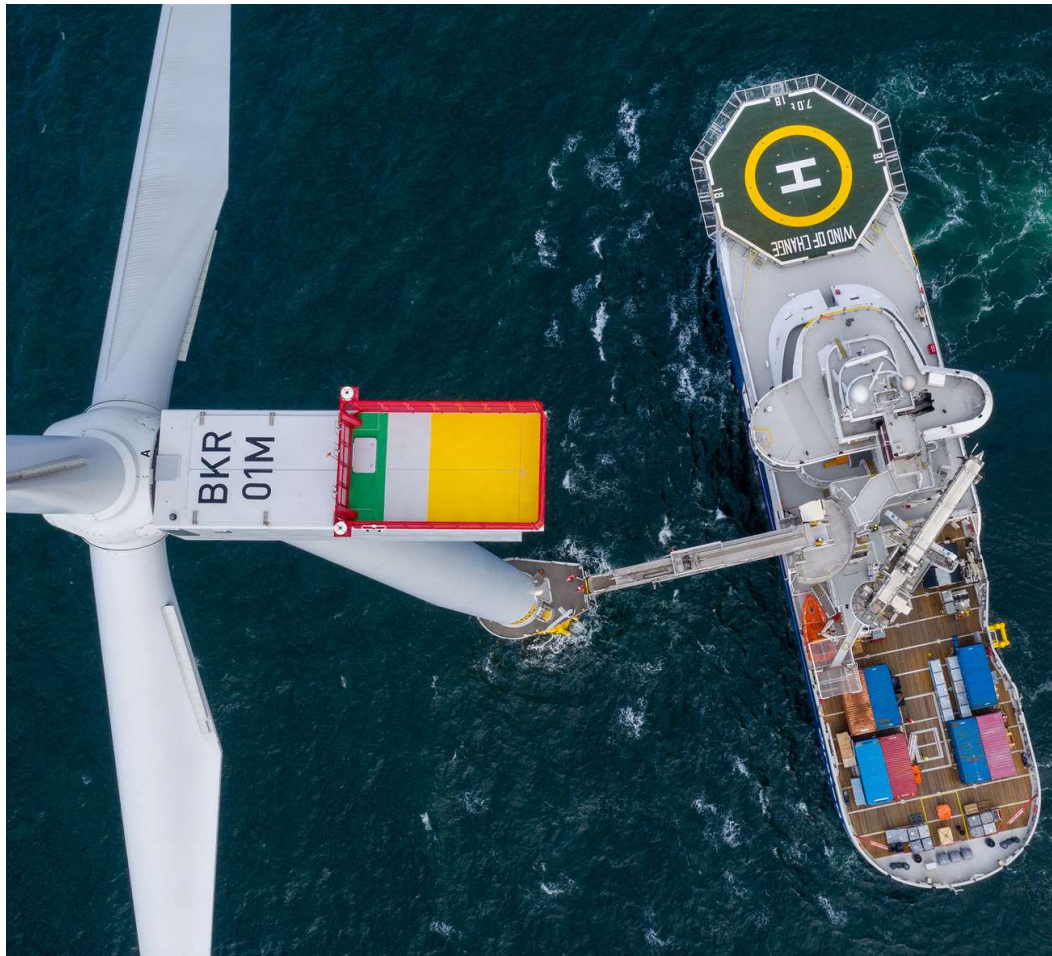
FOREWORD

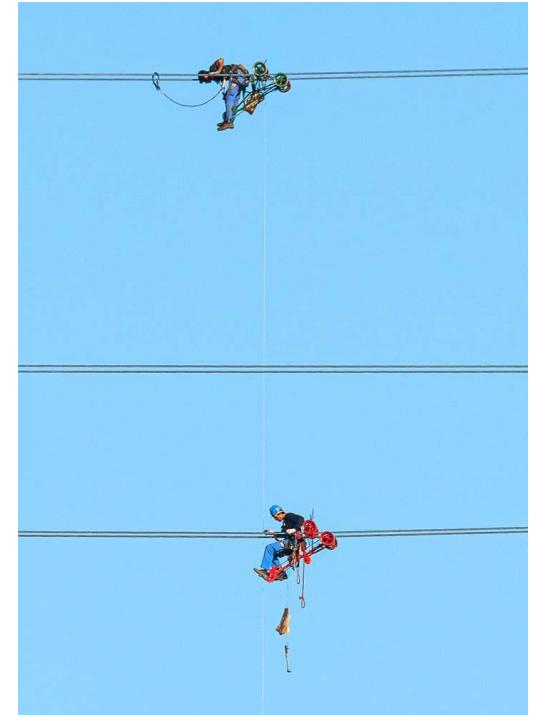














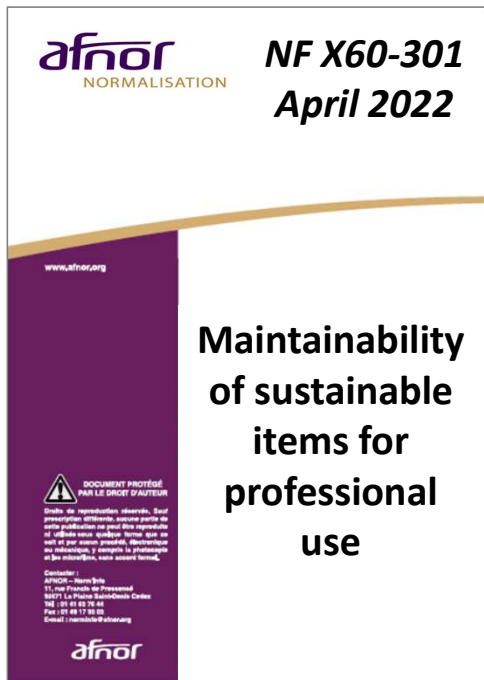


and if it breaks down?!

These systems will only be industrially viable if:
they are **available** ...
... and **their availability is not too expensive**

Maintainability scope and objectives

It concerns:



■ Designers

- better understand and implement maintainability requirements
- consider items maintainability when integrating them on site

■ Manufacturers and assemblers

- better understand how to achieve maintainability objectives.

■ Owners, users and maintainers

- better specify their requirements
- consider maintainability in decisions of acquisition, replacement, rebuilding, renovation, modernization and preservation of assets
- develop efficient maintenance policy and strategy
- help to better predict maintenance costs

Bibliography

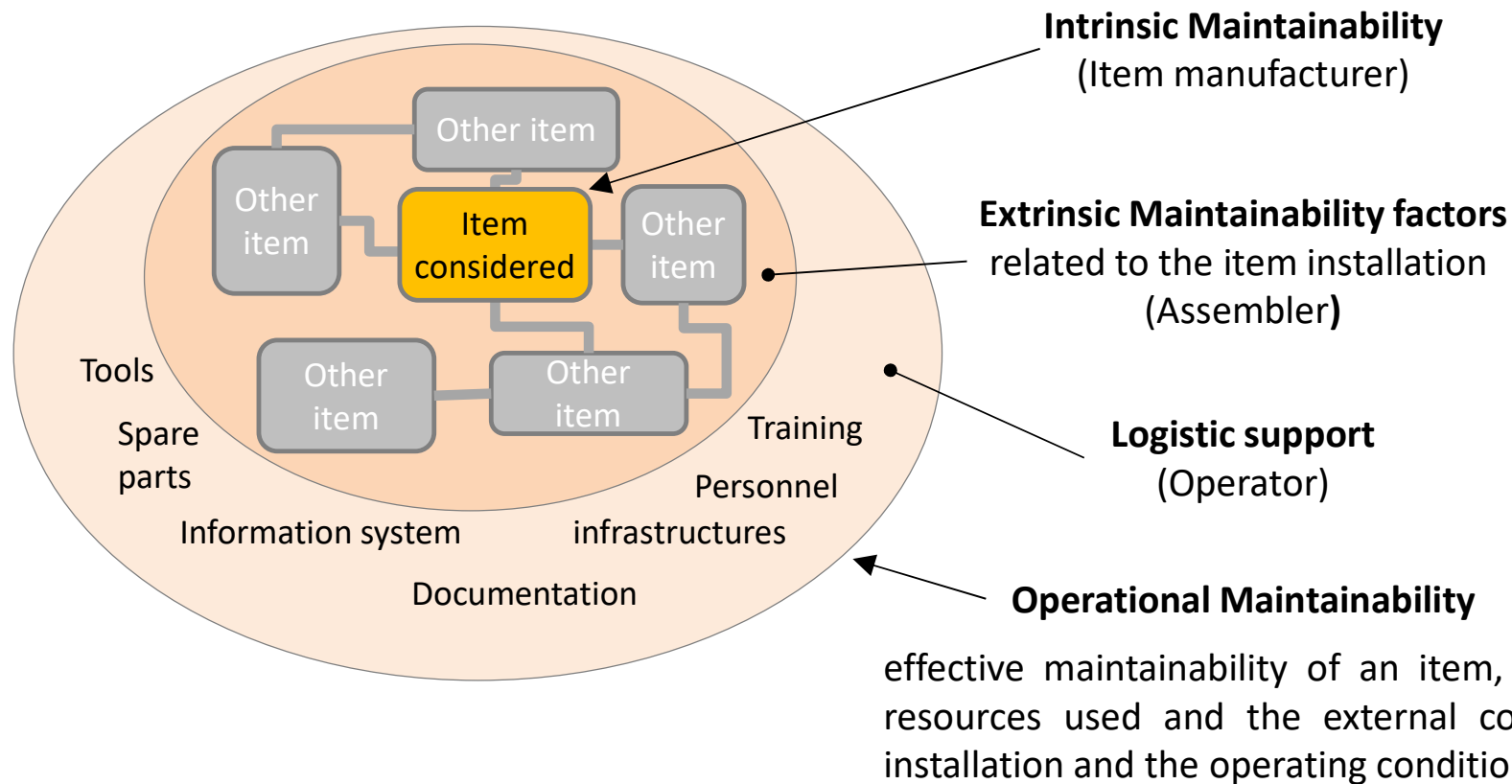
Sustainability

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- ❑ IEC 60300-3-12:2011, *Dependability management – Part 3-12: Application guide – Integrated logistic support*
- ❑ IEC 62550:2017, *Spare parts provisioning*
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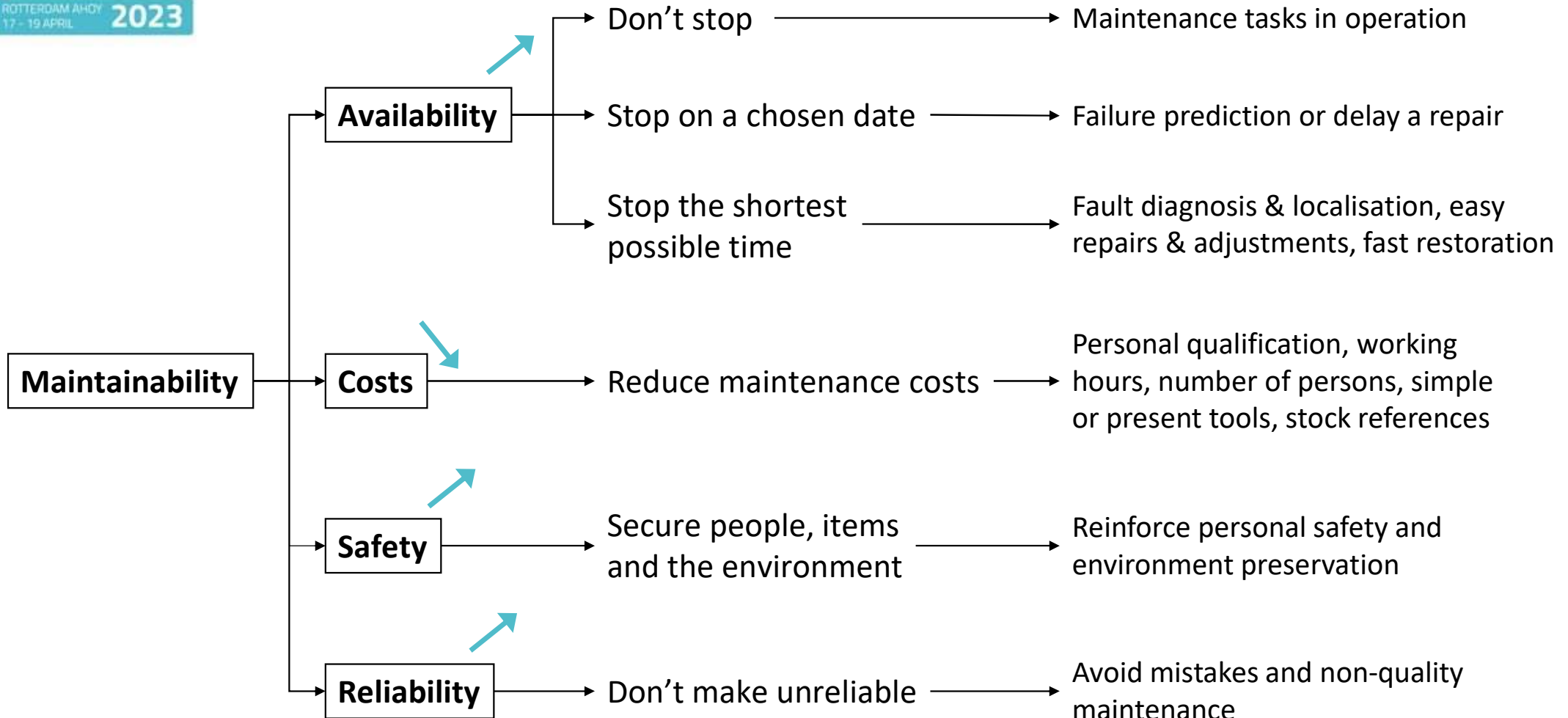
Definition & perimeter

Maintainability [EN 13306: 2017]

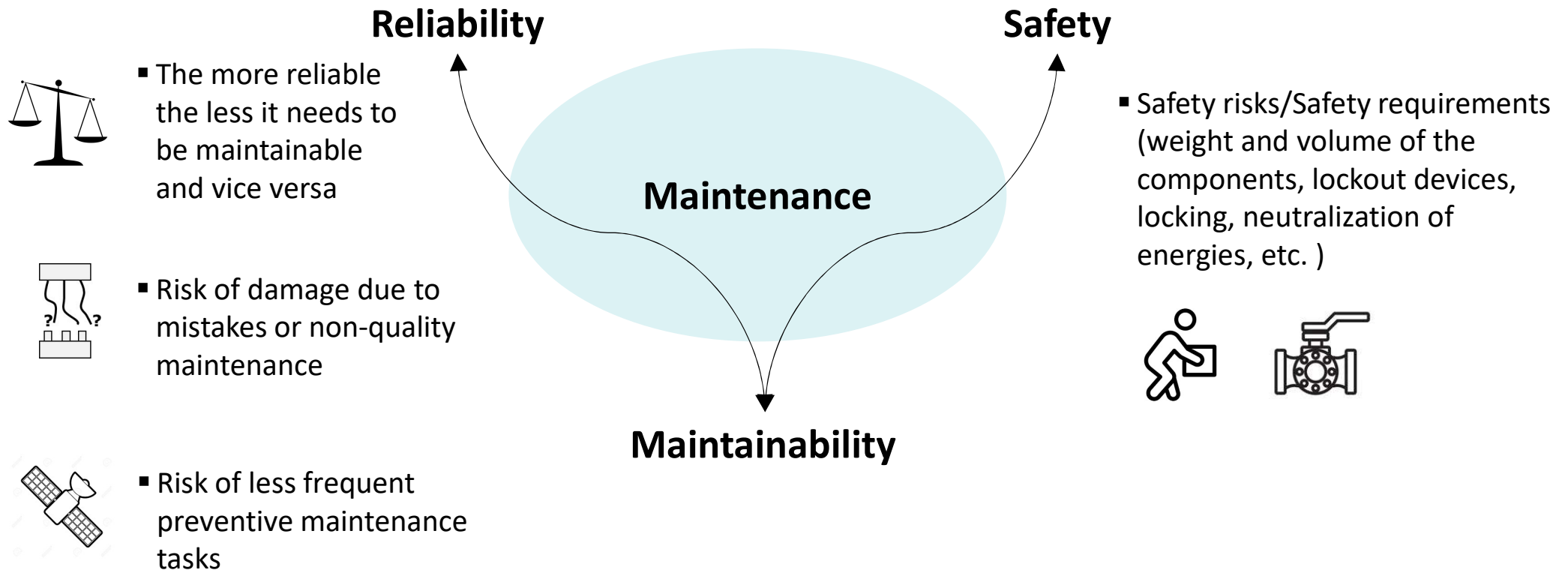
ability of an item under given conditions of use, **to be retained in, or restored to, a state in which it can perform a required function**, when maintenance is performed under given conditions and using stated procedures and resources



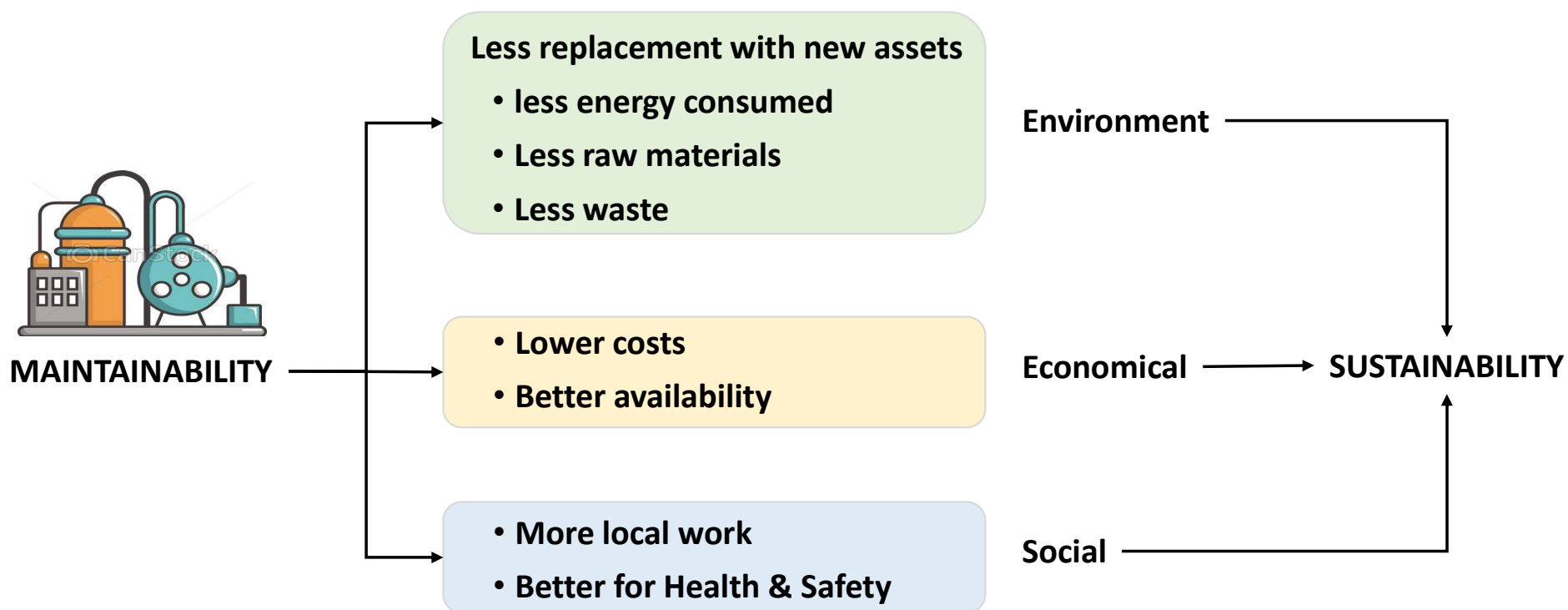
Maintainability objectives



Relationships between maintainability, reliability and safety



Maintainability issues



Maintainability factors related to the item and its installation

- 1) Ability to control risks for people, items and the environment
- 2) Detectability of degradations
- 3) Detectability of failures or faults
- 4) Ability to trigger preventive maintenance
- 5) Ability to be tested prior to restoration
- 6) Accessibility to the item
- 7) Accessibility to components
- 8) Ability to identify and locate
- 9) Disassembly/Reassembly
- 10) Suitability for handling
- 11) Visibility
- 12) Cleanability
- 13) Ability to adjust
- 14) Repairability of components

- 15) Suitability for interchangeability
- 16) Standardization
- 17) Modularity
- 18) Fault tolerance - Capability for degraded operation - Capability for temporary repair
- 19) Redundancy
- 20) Ability of the item to restoration
- 21) Ability to Autonomous Maintenance

Maintainability factors related to logistic support

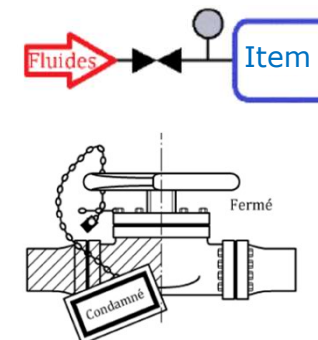
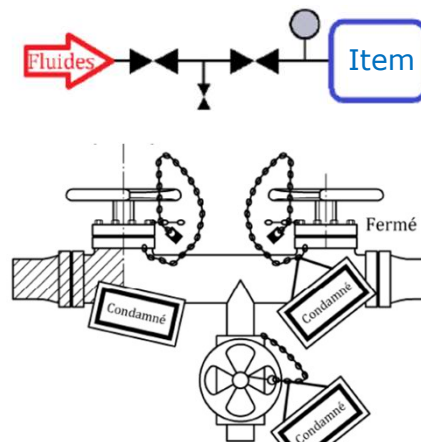
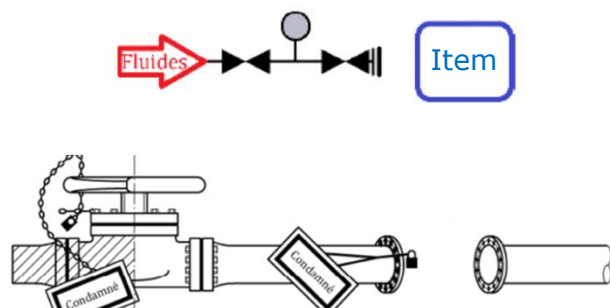
- 22) Technical Documentation
- 23) Tools
- 24) Competences
- 25) Infrastructure
- 26) Articles (spare parts, materials and consumables)
- 27) Ability to group maintenance tasks together to form an optimized maintenance plan
- 28) Perenniality

Maintainability factors related to the item

1) Ability to control risks for people, the item maintained, other items and the environment



- Ability to isolate the equipment from energies, fluids and hazardous substances
 - Identification of energies, fluids and hazardous substances
 - Visually identifiable & accessible safety devices with padlocking systems
- Ability to reduce personal exposure
- Limit PPE and energies
- etc.



Maintainability factors related to the item

2) Detectability of degradations



Ability to allow degradations to be identified and followed to allow preventive maintenance actions

- Sensors or measurement points at appropriate locations
- Sensory possibilities (transparent walls, mobile covers, wear indicators, etc.), shots for image analysis to detect:
 - degradations (loss of material, cracks, pitting, chipping, etc.);
 - symptoms (vibrations, overheating, dirt, etc.).
- Information specifying the admissible thresholds

3) Detectability of faults



Ability to reveal failures or faults to operators and to enable maintenance personnel to identify the origin of the failure.

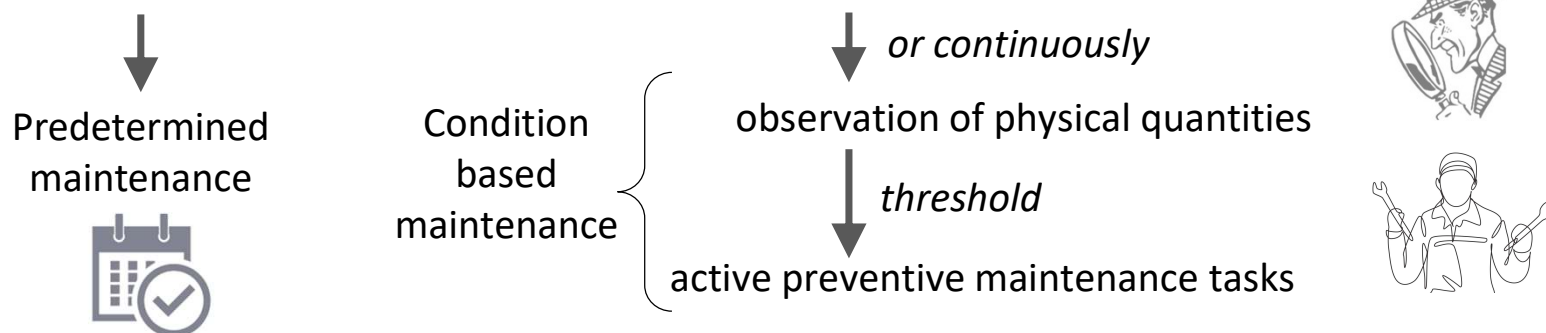
- Alarms for items in operation (low false alarm and inadvertent alarm rates)
- Self-tests, tests on items in standby
- Ease to detect, locate and identify faulty components

Maintainability factors related to the item

4) Ability to trigger preventive maintenance

The ability of an item to trigger preventive maintenance (predetermined, condition based)

Counters of units of use : calendar time, operating time, number of cycles, distance travelled, number of products manufactured, etc.



5) Ability to be tested prior to restoration

Ability to confirm that an item is able to fulfill its required functions before restoration

- Tests carried out on the items → test coverage rate
- Test benches to ensure the operation of the item in its environment of use
- Qualification to ensure incidental or accidental situations

Maintainability factors related to the item

6) Accessibility to the item

Absence of risk, speed of access, depends on:

- Access and protection devices (walkways, nacelles, cooling devices, lifelines, etc.)
- Transport time for spare parts and tools
- Transport to get to work (distance, size of paths, bearable load, etc.)
- Dismantling necessary to access to the item
- Time to restore the environment
- Need of protective personnel equipment (masks, respirators, bulky equipment, etc.)

7) Accessibility to components

Access time to the component and the costs depends on:

- Number of other components to be removed or destroyed
- Mass and size of the components to be handled or moved
- Compliance with anthropometric constraints
- Access and protection devices to be put in place
- Time to reassemble and adjust neighboring components

Careful study for access to wear parts, operating parts, fuses and protection components, attachment points and joints, adjustment points, filters, tanks

Maintainability factors related to the item

8) Ability to identify and locate

→ reduce maintenance time and avoid errors:

- Plans and diagrams, coding of items
- Labelling, marking, identification plate
- Use of colours, pictograms
- Indications of the direction of movement, position markers
- Compliance with standards

Particular attention to measurement points, lockout devices

9) Disassembly/Reassembly

Ability to disassemble/reassemble the components without degrading them, characterized by:

- Simplicity of actions to remove and restore connections between components
- Number of connections
- Number and complexity/specificity of the tools
- Number of persons needed and their qualification
- Number of elements that can no longer be reassembled
- Coding system (poka-yoke)
- Clear identification of the order of disassembly/reassembly of the components

Maintainability factors related to the item

10) Suitability for handling

Facilitate movement, installation and deposit of items, spare parts, tools, etc.

- Type of action to be performed (push/pull, lift, move)
- Spaces (delivery, storage, work areas, etc.)
- Handling equipment required (eg: pallet truck, cart, conveyor, etc.)
- Traffic (routes, avoiding reversing)
- Hooking and gripping devices
- Working situation (height, weight of the load, ...)
- Bulk and stability of the load, dynamic and holding forces required

11) Visibility

Ensuring that the gestures of the maintenance personnel are permanently under their visual control:

- Transparent or easily removable walls, etc.
- Appropriate lighting
- Appropriate location (absence of obstacles, etc.)
- Ergonomic Man-Machine interfaces

Maintainability factors related to the item

12) Cleanability

keep equipment clean:

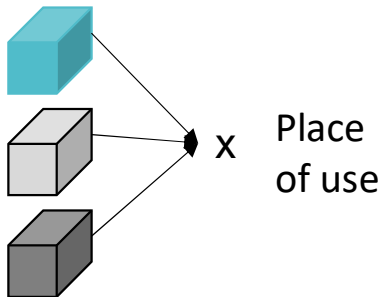
- Preserve useful life and avoid malfunctions due to dust, pollution, etc.
- Detect damage more easily
- Facilitate maintenance tasks (dismantling, etc.)
- Protect people from contact with toxic or pathogenic products (radioactive, chemical, biological contaminants, etc.)

13) Ability to adjust

- Documentation and adjustment procedures
- Tools such as jigs or standards
- Equipment such as sights, adjustment cases
- References such as vibration or sound signatures
- Appropriate means of communication between involved persons (due to distance, noise, etc.)

Maintainability factors related to the item

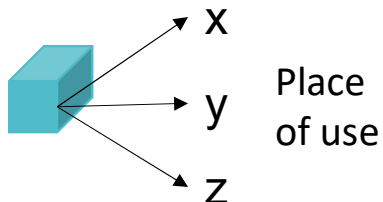
14) Suitability for interchangeability



Possibility of replacing an item with another functionally equivalent item without adaptation

- Identical functions and control system
 - Identical connections, fixings
 - Size and weight compatible with the environment where it is installed
- reduce the consequences of items obsolescence and allow them to be replaced by more dependable items

15) Standardization



Identical or similar items used at different places of use

- Limit the stock of spare parts and simplify their management
- Limit documentation and tooling requirements
- Increase technical expertise and the quality of experience feedback

Particular attention → connections, fixings

Maintainability factors related to the item

16) Repairability of components

Ability to be restored rather than discard and replace it (ex. of non-repairable items : seals, elastomers, cracked materials, etc.). It depends on:

- Technical possibility of a repair
- Ease of disassembly and reassembly of the defective parts and solidity of the assembly parts
- Qualification required
- Necessary tools and availability of spare parts at reasonable price
- Possibility of replacing the defective part with interchangeable or copied part
- Quality of the technical documentation

17) Modularity

Easily removable and replaceable combination of components performing a given function(s)

- Specify: functions, testing devices, connections, fixings, weight, sizes of the modules
- facilitate disassembly, interchangeability, standard exchange item (new or repaired)

Maintainability factors related to the item

18) Fault tolerance - Capability for degraded operation - Capability for temporary repair

Fault tolerance: ability to perform the required function despite failures or faults

Capability for degraded operation: ability to perform the required function in a reduced manner, within defined limits of acceptability

Make it possible:

- Deferred corrective maintenance
- Repairs in operation

19) Redundancy

Case of fault tolerance

Several means (other items) to perform a required function

Redundancy is active or passive (→ risk of hidden failures and faults)

→ Can make it possible to defer corrective actions (spare installed)

Maintainability factors related to the item

20) Ability of the item to restoration

Ability to be available to the user after maintenance tasks

- May require resources (e.g. auxiliary devices), appropriate procedures, and energy
- Lead to technical, logistical or administrative delays
- Measured by MTTR, costs or losses (energy, products, etc.) due to restoration

21) Ability to Autonomous Maintenance

Ability to be maintained by production or control operators (maintenance level #1)

- Simple tasks with a minimum of tools (detection and diagnoses of degradation and failure, replacement/adjustment, ... of components)

→ Improving item availability and reducing maintenance costs

Pay attention to items to be replaced frequently (filters, batteries, consumable materials, etc.)

Maintainability factors related to the logistic support

22) Technical Documentation

- clarity, accuracy and completeness
- standardization of summaries and content
- durability, availability and reproducibility

23) Tools

- limited, simple and standard tools

24) Competences

- Preferably simple and/or standard
- To be define according to maintenance levels

25) Infrastructure

- warehouses, workshops, offices, meeting rooms, library, etc.
- areas for depositing, access, roads, etc.
- energy, fluids (air, water), communication, etc.

26) Spare items (spare parts, materials and consumables)

- item breakdown, reference, nature of spares
- spare parts and materials, documented, durable

27) Ability to group maintenance tasks together to form an optimized maintenance plan

- securing sets of items that are functionally related or dependent on the same energy sources
- maintenance levels and echelons and required skills
- means and tools required

28) Perenniality

- ability to maintain an item without obsolescence

Maintainability assessment

Times

Maintenance time							
Preventive maintenance time				Corrective maintenance time			
Degradation assessment time	Active preventive maintenance time	Function checkout time	Technical & logistic & internal administrative delays	Repair time			Technical & logistic & internal administrative delays
				Fault diagnosis time	Active corrective maintenance time	Function checkout time	

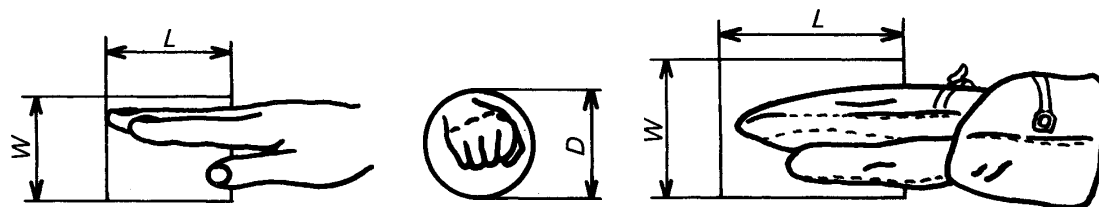
MRT

MTTR

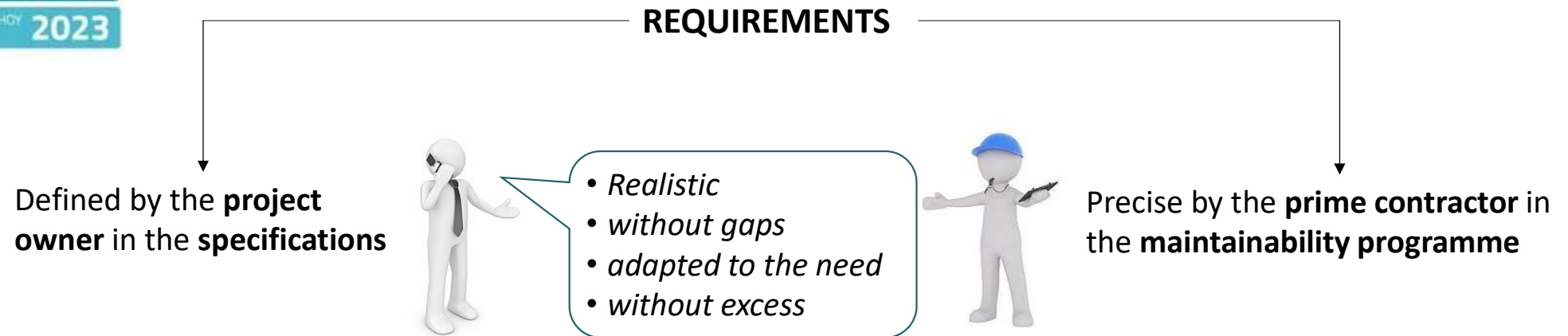
Costs

- Cost of spare items
- Labor costs for maintenance tasks
- Costs of logistic support
- Associated technical costs (e.g.: oil analyses, specific studies and expertise, etc.)
- Costs of possible impacts on production due to maintenance tasks

Anthropometric data



Maintainability requirements



Requirement
related to:

- ☐ **Corrective and preventive maintenance tasks** (maintenance levels (tasks complexity), maintenance echelon, ...)
- ☐ **Maintainability factors** (qualitative or quantitative)
 - Project owner: according to item use and expected performances
 - Prime contractor: requirements precise at more detailed levels
- ☐ Means and procedures **for verifying** maintainability (simulations, tests, ...)
- ☐ **Regulatory records** (e.g. Machinery Directive, documentation, etc.)

Maintainability programme

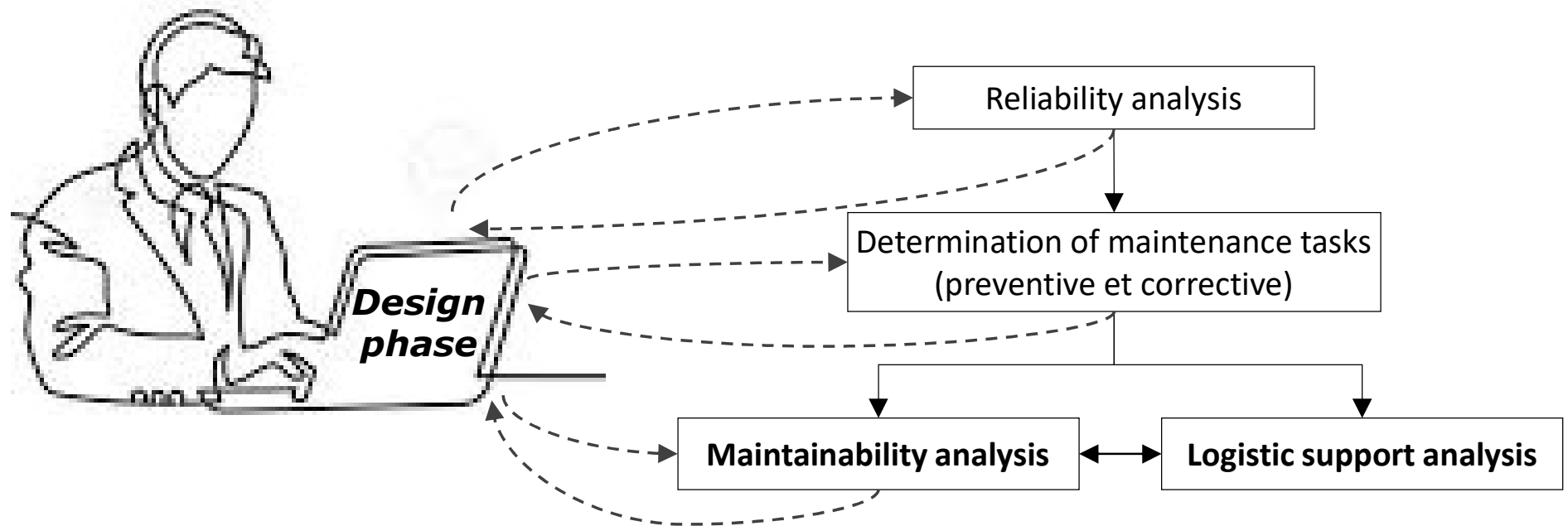
Steps of a maintainability programme:

1. **Identification of basic data** (factors relating to: usage profile, operation and environment, personnel, health and safety, availability, maintenance, logistic support, customer and suppliers, etc.)
2. **Definition of maintainability requirements according to the objectives** (analysis: function, reliability, maintenance, maintainability (including logistical support))
3. **Allocation of requirements to equipment** (distribution to optimize availability and maintenance costs taking into account reliability)
4. **Design** taking into account maintainability and logistic support requirements
5. **Forecasts of the maintainability of the various competing solutions** (times (MTTR, MRT, etc.), costs over the life cycle)
6. **Trade-off analysis** to determine the optimal solution (maintainability factors, forecasts, item reliability, maintenance strategy, functional performance of the item)
7. **Verification of compliance** with maintainability requirements (tests, observations, simulations)
8. **Definition of logistic support** (tools, infrastructure, test facilities, monitoring systems, spare parts, training, documentation, information system)

To conclude

Sustainability

Maintainability → Maintenance → Durability → Sustainability



Questionnaire

EUROMAINTENANCE 2023

Workshop on Maintainability of assets: a pillar of sustainability

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Detectability of failures or faults

- Are all faults or failures detectable (i.e., is there a risk of hidden fault in some items)? Which faults might not be immediately evident?
- If some faults can remain undetected by the operator, are specific actions (periodic testing, external inspections ...) proposed in order to bring these to light?

Predetermined preventive maintenance

- Are there plans to measure the number of usage units (operating time, numbers of start-ups/shutdowns, number of cycles ...) of system equipment to enable scheduling of predetermined preventive actions in order to restore optimal operational conditions (i.e., without observation of a degraded state)?

Safety of maintenance personnel

- Do any of the maintenance actions present health and safety risks to maintenance personnel? Which?
- Is the use of personal protective equipment (PPE) affecting the conditions under which the actions are carried out required for certain maintenance actions? Which?

Cleanability

- Are the equipment/materials of which the system is constituted exposed to dust that may necessitate periodic cleaning or complicate certain maintenance actions? Which equipment/components?